"The place of B.A.C. 3965, is taken from that catalogue. The mean places of the other stars are :—

	Epoch, Jan. 1, 1848. R.A. h m s	N.P.D. ° ′ ″	*Compared by the Instrument with	
a	7 51 48·08	36 49 32·2	B.A.C. 2967	2 Comparisons.
b	10 23 24·35	45 2 23·9	— 3515	1 —
c	11 24 4·89	60 54 48·6	— 3856,3965	
d	12 2 44·82	60 5 9·7	— 4147	2 —

Description of a Machine for Polishing Specula.
By Mr. Lassell.

"The twelfth volume of the *Memoirs of the Royal Astronomical Society* contains a description of a Newtonian Reflecting Telescope, of 9 inches aperture and 112 inches focus, equatoreally mounted in a revolving dome of 14½ feet diameter.

"Several years' experience in the use of this instrument so well convinced me of its general efficiency, and especially of the convenience and stability of its mounting, that I determined, two or three years ago, to carry out precisely the same principle on a much larger scale.

"With a view of informing myself what degree of perfection is attainable in figuring surfaces of larger mirrors than can be wrought by hand, and also of ascertaining the proportion of aperture to focus which it would be most desirable to adopt, I visited Birr Castle; and, by the kindness of the Earl of Rosse, enjoyed the opportunity of two nights' observations with the 3-foot telescope erected by his lordship.

"I was also favoured with an examination of the whole of the machinery employed in grinding and polishing the great speculum; and I returned so well satisfied with all I had seen, that I very shortly resolved to cast a speculum of 2 feet diameter and 20 feet focus.

"The mode of casting the large speculum which I employed involved the principle, discovered, I believe, and first published, by Lord Rosse, of casting the speculum on what is technically called a *chill*, *i.e.* an iron base, slightly warmed, which causes the speculum to cool upwards in horizontal strata.

"Principally, however, from the difficulty of forming it, I did not employ a base constructed with iron hoops placed edgewise, and turned to the gauge, as Lord Rosse recommends, but, instead of it, a *disk* of cast iron, with its upper surface convex, according to the required radius of curvature, and a rebate formed on the edge of its upper surface, which, receiving a stout iron hoop equal in breadth to the thickness of the speculum, formed an iron mould, and dispensed altogether with the use of sand in the casting. The disk does not require to be *turned*, but if cast from a well-made

* The partial results agree as well as those obtained by the best meridian instruments.

wooden pattern will be sufficiently true; neither do I think turning the hoop essential, though it might be well to turn the inside surface and the edges, if the means of doing so were at hand.

"As it is necessary that the pouring should be pretty quick, in order that there may not be time for the base to solidify any portion of the metal before it is completely covered, I inclined the base a little, pouring on the lowest side, in order that the fluid might rise in one compact wave; and when the disk was nearly covered, it was restored to a truly horizontal position, and the pouring continued, until the mould was sufficiently filled, namely, to the depth of about two inches and three quarters. The hoop was about three inches broad, and having been turned parallel, the mould was in the first instance placed horizontal, by a spirit-level being placed upon its edge. The inclination was produced by the application of a lever, which, when withdrawn, restored the base to its horizontal position, and ensured the equable thickness of the speculum at every part of its circumference."

Mr. Lassell then describes the very ingenious method which he adopted to procure the requisite quantity of metal in the proper state, and his mode of ascertaining that the dose of tin was sufficient. The final proportion which he used is 32 lbs. of copper to 15·09 lbs. of grain tin, and 18 lbs. of white arsenic were stirred up with 438 lbs. of the melted mixed metal.

"The speculum was ground and polished on a machine almost precisely the same as that described by Lord Rosse in his lordship's very interesting paper, published in the second part of the *Phil. Trans.* for 1840.

"I found, however, the grinding process much facilitated by interposing a piece of sheet-lead, about a tenth or twelfth of an inch thick, between the speculum and the iron grinding-tool. This saved the rapid wearing down of the tool and also cut the metal much faster, as the softness of the lead suffered the particles of emery to imbed themselves into it, and thus to form a very keen grinding surface. When the lead, fully charged with the emery, had become smooth, it was exchanged for a fresh piece. When an entire surface had been obtained upon the speculum, the smoothing and perfecting of the surface previous to polishing was produced by the iron tool and the finest washed emery.

"The speculum was polished many times on the same machine, following as nearly as practicable the directions given by Lord Rosse; but, after several months' trial, I did not succeed in obtaining a figure which satisfied me, the best I got being very inferior to the surfaces I had obtained by hand on specula of various sizes, up to nine inches diameter. In despair of success by this process, I ultimately contrived a machine, in which I endeavoured to represent as closely as possible the evolutions of the hand, by which I had been accustomed to produce very satisfactory surfaces on smaller specula."

The machine invented by Mr. Lassell, and constructed by Mr. Nasmyth, for figuring and polishing specula, cannot be made intel-

ligible without figures.* The speculum rests with its face uppermost in a horizontal position, and is carried slowly round by a vertical axis. The polisher rests, with its grinding and polishing surface, upon the speculum, and is moved by a pin which fits loosely into a hole in the centre, at the back of the polisher. The motion of the polisher is that of the driving-pin.

Now this, by a very ingenious and very compact mechanism, receives a compound motion which may be thus imagined. Conceive a circular motion given to a point round the centre of the speculum, and then conceive that the driving-pin has a circular motion round this point. The curve is an *epitrochoid*, and the adjustments of the mechanism enable the workman to give any radius to either circular motion, from 0 up to a certain number of inches. The proportions of these radii, in order to give a parabolic figure, are determined experimentally, in which the relation of aperture to focal length must be considered. The size of the polisher, and even the hardness of the pitch, must also be proportioned to the figure and aperture required. Mr. Lassell finds no difficulty in getting a true parabolic figure when the aperture is one-eighth of the focal length.† The speculum, while grinding and polishing, is supported in the same way as it is in the tube when in use. The principle of this mode of support is mentioned by Lord Rosse, *Philosophical Transactions*, 1840, p. 524.

"The polisher should possess as much stiffness as is compatible with the requisite lightness, and I have found these qualities best combined by making it of white American deal, in two strata, well united by glue and a few screws, with the direction of the grain at right angles, the wood well seasoned, and, if possible, cut out of the same board. The polisher for the 2-foot speculum is made out of $1\frac{1}{8}$ inch board, and has, for symmetry, both the upper and under surfaces convex, to fit the speculum. It is about 2 inches thick at the circumference, $20\frac{1}{2}$ inches diameter, and weighs about 12 lbs. with the pitch surface upon it."

Mr. Lassell then enters very minutely into the mode of coating the polisher with pitch evenly and to a proper thickness, of dividing the surface into equal squares, and the various manipulations which are required to produce a perfect result. The grinding powder is known as *rouge*, and the best quality may be had from Mr. Fox of Saffron Hill.

* A model to half the true size, and the drawing by Mr. Nasmyth, may be seen at the Society's apartments. A model of Lord Rosse's engine, and of the mounting, &c. of the 6-foot reflector at Birr Castle, may also be seen. These were made by Mr. Airy, and presented by him to the Society. Mr. Williams will explain the action and details of all the models to any fellow who wishes for information.

† Mr. Lassell has given so full an account of all his processes that we conceive any person of ordinary intelligence would be able to execute them, but they do not admit of compression, and extend beyond the limits of a *Monthly Notice*. It ought to be mentioned that the Earl of Rosse and Mr. Lassell have at all times freely communicated the steps of progress as soon as these became evident to themselves.

"The whole time occupied in obtaining the requisite lustre varies from about one hour to three, and it ought to be steadily advancing throughout.

"A good idea may be formed of the quality of the operation as it proceeds by watching the motion of the tool. It should be regular and uniform, without any apparent labouring or inequality of speed, and the spontaneous motion which the tool has upon the pin as a centre should be slow and regular. No firm adhesion is ever to be allowed between the tool and speculum: this will take place if a due and regular supply of water be not afforded.

"A second application of powder will rarely be required, and never in any quantity, but many applications of water probably will, and the more rapidly the polish is advancing the more frequently will water be required. It is best applied through a hole in the back of the polisher as near the centre as is convenient, which may perhaps be at about the distance of one-third of the radius. But care should be taken not to give the water in excess. The speculum must never be *dry*, but there must be no superfluous water. It is very conveniently applied with a flat camel's-hair brush, half or three-quarters of an inch broad; but as much as the brush would take up would generally be too much for one application. Towards the end, the water should be added more sparingly, and if needful more frequently, going as near to dryness as may be but *never reaching it*.

"The lustre in this state of the process advances most rapidly. If the process has gone on well the powder will have become almost black at the close. The machine having been stopped, the tool is to be carefully taken off by a sliding motion, and the speculum may then be cleaned with a soft linen cloth or leather; or it may be washed with a soft sponge and water, and then dried, and ultimately rubbed lightly with some very soft wash-leather. If the polishing has apparently wrought smoothly, and the aspect of the tool when taken off, both during the process and at its close, is everywhere of even texture when viewed by an oblique light, the speculum will most likely have a *uniform* curve of some description, whether parabolic or not, for it is a characteristic quality of this machine generally to produce a uniform curve. The quality of the curve is best examined by placing the mirror in its tube, and, by means of diaphragms, exposing separate portions of the mirror of equal area from the centre to the circumference."

"I have been accustomed to produce by hand surfaces of, I believe, great excellence, on various sized specula up to nine inches diameter, of which I may instance my 9-foot equatoreal, which enabled me to discover independently (for I did not previously know of its existence) the sixth star in the trapezium of *Orion*, and with which also the observations of a second division of the ring of *Saturn* were made, as described in the *Astronomical Notices*, vol. vi. p. 11. Such surfaces as these were, however, produced with some degree of anxiety, much manual labour, and perhaps some admixture of accident, especially in the union of a perfectly para-

bolic curve with regularity of surface. The superiority of the machine in these respects is so striking as almost to put comparison out of the question.

"If driven by a steam-engine the manual labour is of course annihilated. The control over the machine, by the setting of the cranks, is such, at least with all foci not less than eight diameters of the speculum, that the curve can be changed almost at pleasure from the spherical side to the hyperbolic side of the parabola, and *vice versâ*; the alterations of the curve being, *cæteris paribus*, almost exactly commensurate with the adjustments of the cranks. In fact, one of the most anxious and laborious operations is, by this machine, converted into an intensely interesting amusement. With moderate care and a little experience a *bad* figure never need to be feared, though it may require two or three successive trials to satisfy the fastidiousness of a cultivated and long-practised eye. The lustre of polish transcends even my best efforts by hand, and is the easiest quality of all to obtain; and however erroneous the figure may be after any unsuccessful effort, the proper curve may be recovered without resorting to the grinder, or indeed materially impairing the polish—at least, I have not found it needful, even when the difference of foci of the central and exterior portions of a mirror has amounted to fifteen hundredths of an inch. In 3 or $3\frac{1}{2}$ hours by the polisher alone, it is possible to annihilate an error even as enormous as this. I have a strong persuasion that this machine might prove eminently serviceable in working the curves of object-glasses of large dimensions, though of this I have no experience."

Mr. Lassell then briefly describes the mounting of the telescope, the form, weight, and dimensions of its component parts, and the covering dome. They are in *principle* almost the same as were used on a smaller scale in his 9-foot Newtonian. There is a very good model of the dome and mounting, presented by Mr. Lassell, at the apartments of the Society.

"To afford some notion of the degree of facility attained in the management of so large a dome and telescope, I may mention, that with an assistant I can, without hurry, place an object, invisible to the naked eye, within the field of the telescope in nine or ten minutes from leaving my house. This includes opening the dome, uncovering the large speculum, attaching the eye-piece, setting from the catalogue for the object, and turning the dome to the required azimuth. Without an assistant, I should require three or four minutes longer, which would be principally occupied in opening the shutters of the dome."

"One of the greatest difficulties I have encountered in supporting the speculum in its various positions equably, is to avoid the effects of the friction of its edge under considerable changes of altitude of the telescope."

"It is obvious, that when the altitude is low, the principal part of the weight of the speculum must be borne upon its edge, and the supporting plates being thus in a great measure relieved from the pressure of the speculum, must, by their elasticity, tend to distort

the metal by pressure at its back; and when the telescope is moved towards the zenith, the plates yield again by the weight of the speculum, while the lower edge, still in hard contact at the points of support, is unduly borne up there, and the equilibrium is destroyed. To remedy this evil I have slung the speculum in a hoop of thin iron, equal in length to half its circumference, the ends of the hoop being attached to swivels fixed in each of the two horizontal brackets, and the lower part of the hoop being thus quite at liberty to rise and fall with the plates.

"This has nearly, if not entirely, removed all perceptible distortion; yet in some positions, and under some circumstances, vestiges of it are to be perceived. I have devised a plan of supporting the metal laterally by an equal tension on the several points of support, and think it may probably be useful; but I have not yet had leisure to carry it into effect.

"Instead of a plane speculum I usually employ a prism, which transmits a pencil two inches in diameter, made for me by Messrs. Merz and Son, of Munich. I am persuaded, from repeated experiments, that the prism has an obvious advantage in light over a speculum, and the material is so fine, and the surfaces so exquisitely wrought, that no perceptible injury of the image exists. The only care necessary in the use of the prism is to preserve it from dew, which it is extremely liable to collect; this I have remedied by having a chamber made in the mounting of the prism, which receives a cube of cast iron enveloped in thick *felt:* this, being moderately warmed and placed in the chamber, effectually prevents the deposition of dew for at least some hours, while the extremely slow radiation through the felt does not produce any sensible disturbance in the formation of the image. The prism is rather small, for though it transmits the entire pencil, there is scarcely any thing to spare, and had it been easy to obtain a sufficiently good one half an inch larger, I should have procured it."

A short Notice of the Equatoreal of the Liverpool Observatory. By Mr. Hartnup.

As the Astronomer Royal will probably give some account of this instrument, which has been constructed on his recommendation and entirely under his superintendence, Mr. Hartnup states, in a few words, that it is of the English construction; that is, the telescope is a transit supported at each end, between two long supports which form the polar axis. The telescope is by Merz of Munich, $8\frac{1}{2}$ inches in aperture, and 12 feet focal length. The circle and declination-circle are each 4 feet in diameter, divided by Mr. Simms upon his "self-acting circular dividing engine."* The

* Described in Vol. xv. of the *Memoirs*. The new altitude and azimuth instrument at Greenwich, which was divided on the same engine, is considered by Mr. Airy to be exceedingly well divided.